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GB 2246151 A US 4637479 A

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UK CL (Edition M ) E1F FCU
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(54) **Directional drilling method and apparatus**

(57) A method for causing deviation of borehole being drilled by rotary drilling uses a bit having at least one nozzle 42 through which a drilling fluid is caused to flow such that in use, the flow of drilling fluid through the nozzle allows one sector of the bit to cut more effectively than the remainder of the bit, the method comprising modulating the flow of the drilling fluid through the nozzle such that the cutting action of the one sector is optimised when in the desired direction of deviation and such that the cutting action of the one sector is reduced at other locations in the borehole as the bit rotates. Apparatus for controlling the direction of drilling of a borehole comprises a rotary drill bit having at least one nozzle for a drilling fluid to flow therethrough, the flow of drilling fluid through the nozzle over cutting structures on the bit causing one section of the bit to have a comparatively improved cutting action with respect to the remainder of the bit; means being provided to modulate the flow of drilling fluid through the nozzle so as to modulate the cutting action of the one section such that the comparatively improved cutting action occurs in a desired direction of deviation of the hole.

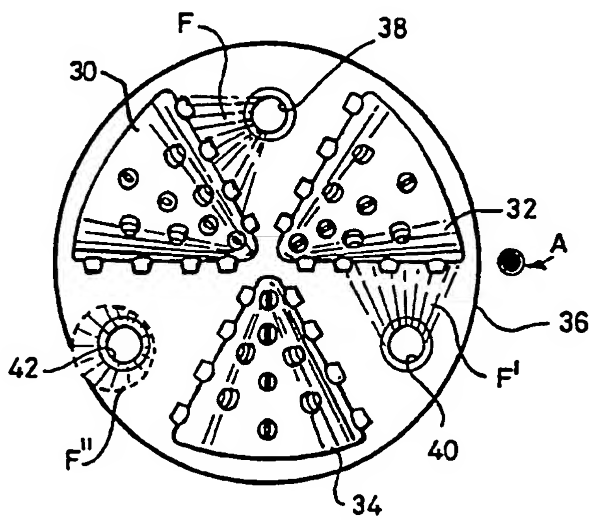


Fig. 4

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

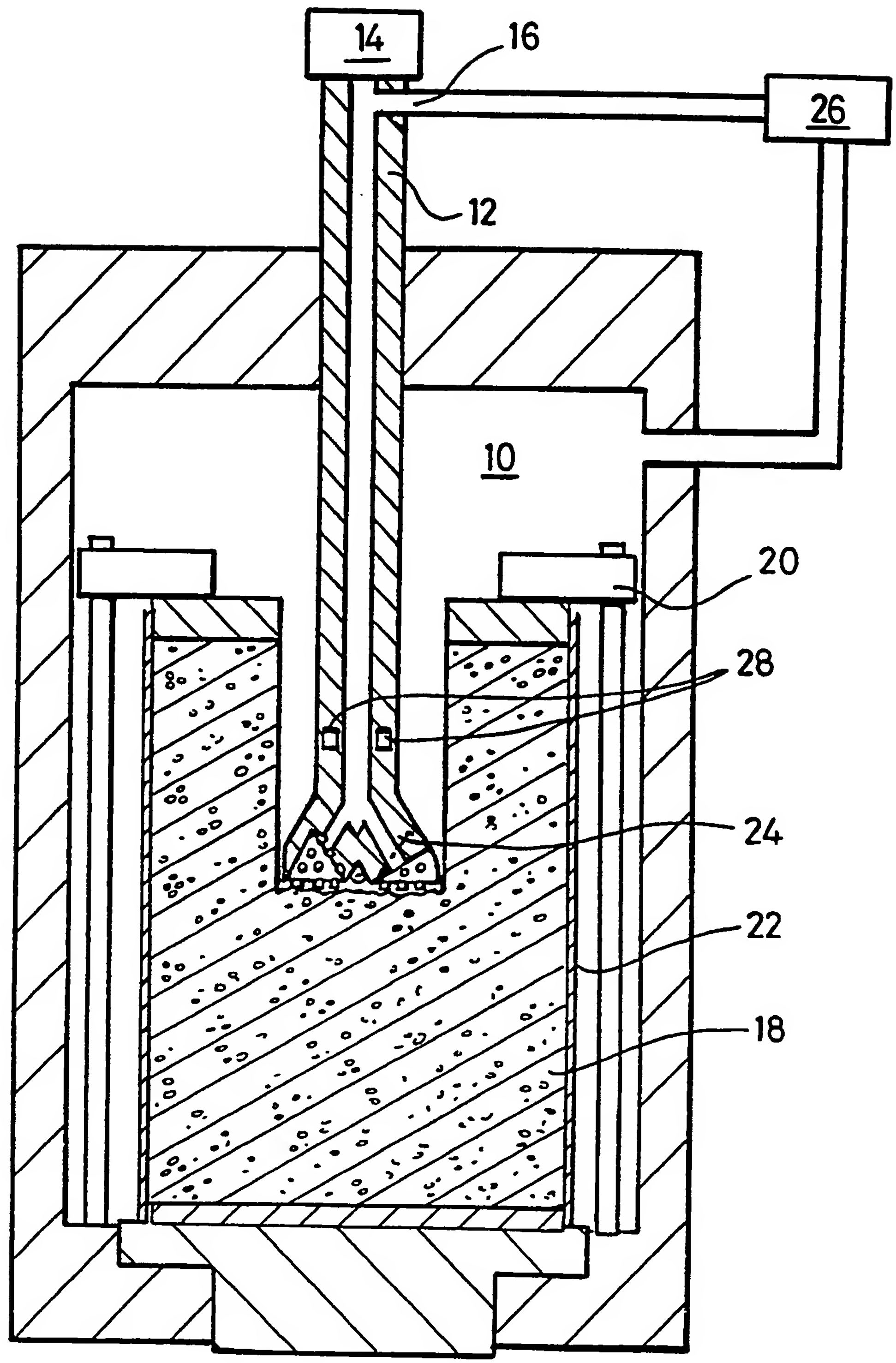


Fig. 1

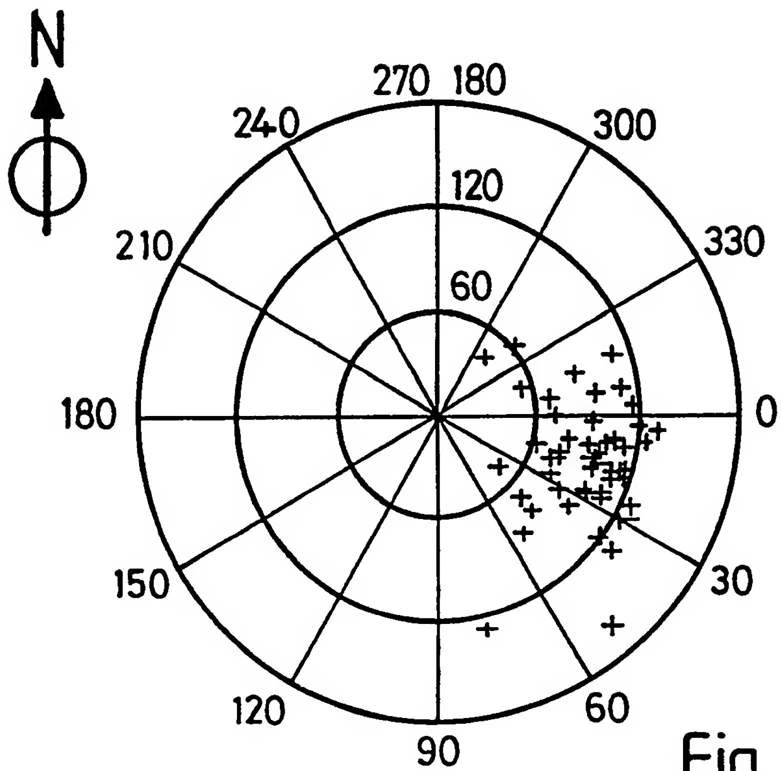
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Fig. 2

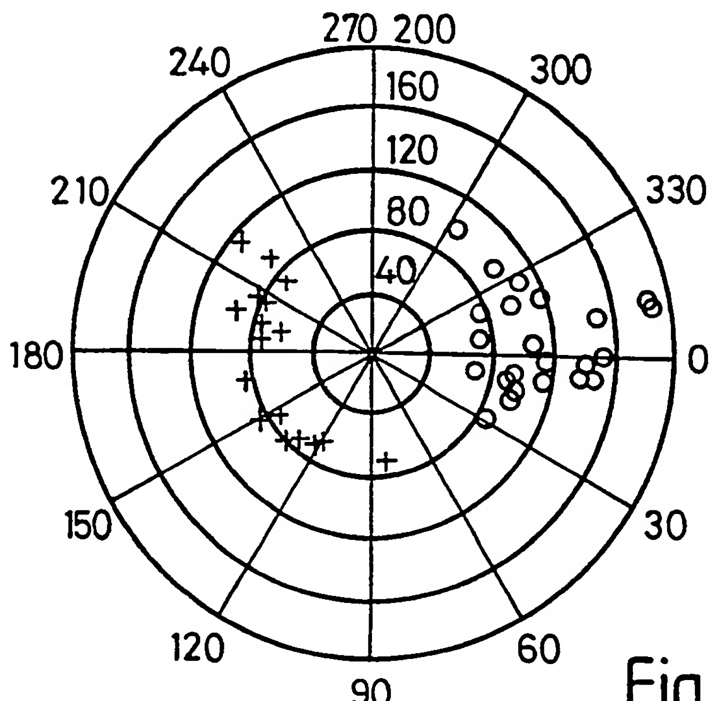
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Fig. 3

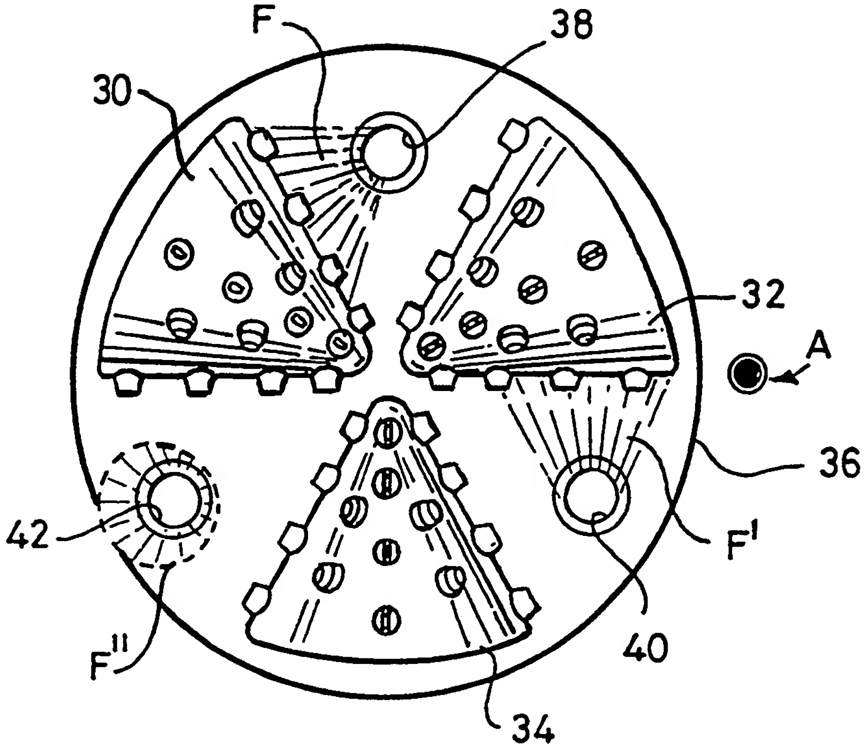


Fig. 4

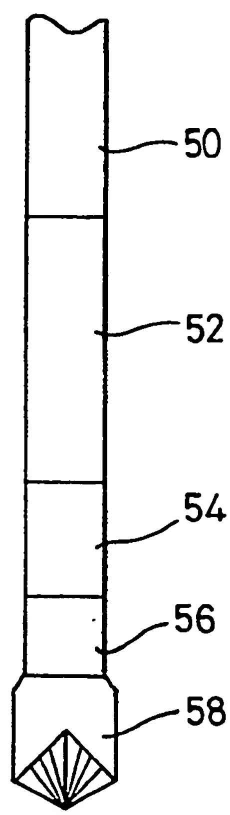


Fig. 5

## Directional Drilling Method and Apparatus

The present invention relates to a method and apparatus for controlling the direction of progress when drilling a borehole such as an oil or gas well.

When drilling a borehole such as an oil or gas well, it is desirable to be able to control the direction of progress of the hole during drilling since it is often impossible or undesirable to drill vertically from the surface to reach the target formation. For example, when drilling offshore, it is common practise to drill several boreholes from a single location which radiate out in different directions. This is because it is economically undesirable to have to relocate the drilling structure (semisubmersible rig, jack-up rig, drilling platform) to drill several wells which are relatively close together. Also, where the producing formations extend horizontally yet are relatively thin, it is desirable that the borehole should remain in the producing formation for as long as possible rather than passing through it perpendicularly in order to optimise production therefrom.

Currently, the most commonly used method of controlling the direction of drilling is to use a downhole motor and a bent sub near to the bit. In such a case, the initial, vertical part of the well is drilled using a usual rotary drilling technique. When it becomes desirable to deviate the drilling from vertical, the drill string is pulled and a directional drilling BHA is used which comprises a bent sub, typically having a bend of $1/2$–3° and a downhole motor which is powered by the flow of drilling mud therethrough and which serves to rotate the bit without the need for drill string rotation. The drill string is then turned until the bent sub points the bit in the desired direction. Drilling is then commenced by rotating the bit using the downhole motion and sliding the drill string into the hole. Once the required deviation has been achieved, rotary drilling can recommence to hold, build or drop from the new direction using a straight BHA. There are certain problems with this approach. The rate of penetration when drilling with the downhole motor is lower than with rotary drilling, there is a higher likelihood that the drill string will be affected by differential sticking and the time taken to change the BHA reduces the rate of progress further. Consequently, it is desirable to provide directional control while rotary drilling.

It has been proposed in US4637479, incorporated herein by reference, to provide directional control by controlling the flow of drilling fluid through jets in the bit so as to make the bit drill more effectively in one section of the hole compared to the remainder of the hole. This is achieved by sequentially opening and closing the jets in the bit as the bit rotates so that the jets

only operate in one section of the hole causing improved cutting by the bit in that section and causing the path of the bit to deviate.

The present invention seeks to provide a system for directional control while rotary drilling which utilises the effect of modulating flow of drilling fluid through the bit yet which does not require the sequential opening and closing of the jets in the bit and so does not require the associated valving arrangement and fluid supply to the jets.

In accordance with a first aspect of the present invention, there is provided a method for causing deviation of borehole being drilled by rotary drilling using a bit having at least one nozzle through which a drilling fluid is caused to flow such that in use, the flow of drilling fluid through said at least one nozzle allows one sector of the bit to cut more effectively than the remainder of the bit, the method comprising modulating the flow of the drilling fluid through said at least one nozzle such that the cutting action of said one sector is optimised when in the desired direction of deviation and such that the cutting action of said one sector is reduced at other locations in the borehole as the bit rotates.

The present invention has the advantage over the prior art technique that it does not require each nozzle in the bit to be independently controllable when more than one jet is present. It is the overall flow through the bit which is modulated. The flow through the nozzles creates an asymmetry in the cutting action which can be used to control the deviation.

A second aspect of the invention provides apparatus for controlling the direction of drilling of a borehole comprising a rotary drill bit having at least one nozzle for a drilling fluid to flow therethrough, the flow of drilling fluid through said at least one nozzle over cutting structures on said bit causing one section of said bit to have a comparatively improved cutting action with respect to the remainder of the bit; means being provided to modulate the flow of drilling fluid through said at least one nozzle so as to modulate the cutting action of said one section such that the comparatively improved cutting action occurs in a desired direction of deviation of the hole.

The means for modulating the flow preferably forms part of the BHA and can include further means for synchronising the modulation with the rotation of the drill string. Where more than one nozzle is present, the flow of drilling fluid is modulated through all nozzles at the same time. The means for modulating the flow is conveniently a flow interrupter.

The further means for synchronising the modulation of the drilling fluid can include accelerometers and/or magnetometers to detect the rotary position of the drill string. The further means can also include means for detecting signals from the surface, such as pressure pulses in the drilling fluid supply to control the modulation and hence the direction of drilling. Also means for communicating the position of the bit to the surface, again such as pressure pulse telemetry, can be included

The nozzle arrangement in the bit can comprise a single nozzle which directs a flow at one part of the bit. Alternatively, a number of nozzles can be used and arranged such that the flow from the nozzles is directed to give the desired effect regarding the cutting action of the bit such as directing the flow from one nozzle at the workface and the flow from any other nozzles at the cutting structures and the bit to act as mud picks. Additionally or alternatively the internal geometry of the nozzles can be selected such that there is greater flow in the appropriate section of the bit compared to the remainder of the bit.

The present invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 shows a test rig for demonstrating the present invention;

Figure 2 shows a plot of results of a drilling test with deviation in one direction;

Figure 3 shows a plot corresponding to Figure 2 with the direction of deviation changed during the test;

Figure 4 shows a bit for use in a method on apparatus according to the present invention; and

Figure 5 shows a schematic view of apparatus according to the present invention.

Referring now to Figure 1, the test rig comprises a chamber 10 into which a drill shaft 12 projects. The drill shaft 12 is connected to a motor 14 and drilling fluid supply 16. Inside the chamber a sample of rock 18 is located below the drill shaft 12. A mechanism 20 is provided to apply an overburden stress to the sample drill shaft and a confinement system 22 is provided so as to control the pore-pressure of fluids in the sample. In use, a bit 24 is mounted on the drill shaft 12 and is drilled into the sample under the influence of the motor 14. Drilling fluid is circulated through the drill shaft 12 and bit 24 by means of a pump 26. The drilling fluid exits the bit and hole being drilled in the sample and the effective pressure in the hole at the bit

(bottom hole pressure) is controlled by an intensifier where the drilling fluid leaves the chamber. Any tendency of the bit to deviate from a straight path when drilling is detected by means of shear sensors 28 in the drill shaft above the bit.

The test rig is used to provide the results plotted in Figures 2 and 3.

The flow rate from the pump is approximately 110 L/min. The flow rate to the bit is controlled by a control valve. This allows all of the flow through to the bit or dumps some of the flow to the well bore annulus through nozzles. The valve opening and closing is synchronised to the rotation of the bit, thus the flow to the bit is high (approximately 90% of flow rate) for 120 degrees of bit rotation and then reduced (to approximately 10%) for 240 degrees of rotation. During the low flow to the bit period, the flow is diverted to the well bore through nozzles thus maintaining a constant pressure drop between pump discharge and bottom hole.

The valve opens and closes on every rotation of the bit. Rotary speed is 30 RPM. The high to low flow period depends on the design of the valve switching element. For these tests the valve element is designed for 120 degree high flow and 240 degrees low flow, however there is some overlap between the high and low periods so that the actual high flow period is somewhat greater than 120 degrees.

Test Details

Samples: Richemont limestone.

Bit: 3/18" tri-cone, modified with two 'mud pick type' nozzles and one 'jetting nozzle', jetting into the corner of the wellbore.

Mud: Water based CMC polymer with a PV of 12.5 and a YP of 2.5.

WOB : approximately 4.5 kN.
(weight on bit)

SDPP : 7.6 MPa.
(surface drill pipe pressure = pump discharge pressure)

SBHP : 3.0 MPa.
(surface bottom hole pressure = annulus pressure)

Rock confining pressure: 4 MPa.

Rock overburden pressure: 1.5. MPa.

Mud temperature: 18 to 24$^{o}$

Figure 2 shows a plot of the bending moment compared to the rotary position of the drill bit. In this case, the high flow period occurs when the 'jetting' nozzle is in the 120° segment

centred on 0° (east). The bending moment is shown as a + on the plot and coincides with the preferential jetting mud thus cutting action due to the flow pulsing.

The test plotted in Figure 3 comprises initially a repeat of the test plotted in figure 2 and shown as o on the plot. Half way through the test, the flow pulsing was shifted by 180° such that the high flow occurred when the 'jetting' nozzle was in the segment centred on 180° (west) and is represented as + on the plot.

The bit used in these tests is shown in Figure 4 (viewed from below) and comprises a rollercone bit having three cones 30, 32, 34 mounted on a bit body 36. Drilling fluid nozzles 38, 40, 42 are located in the bit body 36 between the cones 30, 32, 34 and area arranged such that two of the nozzles 38, 40 direct flow F, F' of the drilling fluid directly at adjacent cones 30, 32 to act as mud picks and do not direct any flow at the workface. The remaining nozzle 42 directs flow F" into the corner of the workface. Thus the flow of drilling fluid is assymetric relative to the bit and because of the direction of flow from the nozzles, the portion of the bit near nozzle 42 will have a relatively improved cutting action relative to the remainder of the bit when drilling fluid is flowing from the nozzles. This difference becomes greater as the flow of drilling fluid through the bit increases. Thus if the flow of drilling fluid is pulsed such that the flow is high whenever nozzle 42 passes point A on the workface and low for the remainder of the rotation, the bit will drill prefemtially in the direction of point A. While the bit still cuts better near nozzle 42 when the flow is low, the difference compared to the rest of the bit is small and is significantly less that the cutting effect when the flow is high. Clearly the flow of drilling fluid has to be modulated according to the position of the bit (nozzles) relative to the workface and this is best done once per revolution although lower frequencies can be used.

It will be appreciated that the exact number and type of nozzles used can be varied while still maintaining this effect. In its simplest case, only one nozzle is required (for example nozzle 42) but this can lead to problems with bit balling in certain circumstances, hence the other nozzles 38, 40 in Figure 4.

The complete BHA for performing the method according to the present invention is shown schematically in Figure 5. The BHA shown in Figure 5 is connected to a drill string 50 through which a drilling fluid is pumped from the surface and comprises an MWD and mud pulse telemetry package 52 which, inter alia, allows communication between the BHA and surface equipment by means of positive pressure pulses in the drilling fluid. The MWD package 52 includes a generator driven by mud flow to provide power for the various parts of the BHA. Below the MWD package 52 is a direction measuring tool 54 which measures the direction and

inclination of the BHA in the borehole and hence provides an indication of the direction of drilling at a given time. Information from the direction measuring tool 54 is passed to the surface via the MWD package 52. A flow modulator 56 is located adjacent to the direction measuring tool 54 and serves to modulate the flow of drilling fluid through the bit 58 so as to cause the deviation in the direction of drilling. The bit 58 has the assymetric flow pattern through the nozzles as described previously. The flow modulator 56 includes a sensor to indicate the position of the bit in the borehole during rotation and causes the flow of drilling fluid through the bit 58 to be modulated according to the postion of the bit 58 relative to the workface as described in relation to Figure 4. Instructions are provided from the surface via the MWD package 52 to the modulator 56 to control the direction of drilling. The direction measuring tool 54 provides an indication of the current path of the borehole and the modulator 56 is controlled to cause the bit 58 to deviate in the desired direction.

## CLAIMS

1. A method for causing deviation of borehole being drilled by rotary drilling using a bit having at least one nozzle through which a drilling fluid is caused to flow such that in use, the flow of drilling fluid through said at least one nozzle allows one sector of the bit to cut more effectively than the remainder of the bit, the method comprising modulating the flow of the drilling fluid through said at least one nozzle such that the cutting action of said one sector is optimised when in the desired direction of deviation and such that the cutting action of said one sector is reduced at other locations in the borehole as the bit rotates.

2. A method as claimed in claim 1, wherein the modulation of the flow of drilling fluid is synchronised with the rotation of the bit in the borehole during drilling.

3. Apparatus for controlling the direction of drilling of a borehole comprising: a) a rotary drill bit having at least one nozzle for a drilling fluid to flow therethrough, the flow of drilling fluid through said at least one nozzle over cutting structures on said bit causing one section of said bit to have a comparatively improved cutting action with respect to the remainder of the bit; and b) a modulator which operates to modulate the flow of drilling fluid through said at least one nozzle so as to modulate the cutting action of said one section such that the comparatively improved cutting action occurs in a desired direction of deviation of the hole.

4. Apparatus as claimed in claim 3, wherein the modulator forms part of the BHA.

5. Apparatus as claimed in claim 3 or 4, wherein the modulator is a flow interrupter.

6. Apparatus as claimed in any of claims 3 - 5, including synchronising means which synchronise the modulation of the flow of drilling fluid with the rotation of the drill string.

7. Apparatus as claimed in claim 6, wherein the synchronising means further includes accelerometers and/or magnetometers to detect the rotary position of the drill string.

8. Apparatus as claimed in claim 6 or 7, wherein the synchronising means also includes a detector for detecting signals from the surface.

9. Apparatus as claimed in any of claims 3 - 8, further including a transmitting device for communicating signals indicative of the position of the bit to the surface, again such as pressure pulse telemetry, can be included

10. Apparatus as claimed in claim 8, or 9 wherein the signals comprise pressure pulses in the drilling fluid.

11. Apparatus as claimed in any of claims 3 - 10, wherein the nozzle arrangement in the bit comprises a single nozzle which directs a flow at one part of the bit.

12. Apparatus as claimed in any of claims 3 - 10, wherein the nozzle arrangement comprises a number of nozzles.

13. Apparatus as claimed in claim 12, wherein the flow from one nozzle is directed at the workface and the flow from any other nozzles is directed at the cutting structures on the bit to act as mud picks.

14. Apparatus as claimed in claim 12, wherein the internal geometry of the nozzles is such that there is greater flow in the one section of the bit compared to the remainder of the bit.

Amendments to the claims have been filed as follows

1. Apparatus for controlling the direction of drilling of a borehole, the apparatus comprising: a rotary drill bit having at least one nozzle for a drilling fluid to flow therethrough in such a manner that the flow of drilling fluid through that nozzle over cutting structures on the bit causes one section of the bit to have a comparatively improved cutting action with respect to the remainder of the bit; and modulator means to modulate the flow of drilling fluid through that nozzle so as to modulate the cutting action of the section such that the comparatively improved cutting action occurs in a desired direction of deviation of the hole.

2. Apparatus as claimed in Claim 1, wherein the modulator means forms part of the bottom hole assembly.

3. Apparatus as claimed in either of the preceding Claims, wherein the modulator means is a flow interrupter.

4. Apparatus as claimed in any of the preceding Claims, including synchronising means which synchronises the modulation of the flow of drilling fluid with the rotation of the drill string.

5. Apparatus as claimed in Claim 4, wherein the synchronising means includes accelerometers and/or magnetometers to detect the rotary position of the drill string.

6. Apparatus as claimed in Claim 4 or 5, wherein the synchronising means also includes a detector for detecting signals from the surface.

7. Apparatus as claimed in any of the preceding Claims, further including a transmitting device for communicating to the surface signals indicative of the position of the bit.

8. Apparatus as claimed in Claim 6 or 7, wherein the signals comprise pressure pulses in the drilling fluid.

9. Apparatus as claimed in any of the preceding Claims, wherein the nozzle arrangement in the bit comprises a single nozzle which directs a flow at one part of the bit.

10. Apparatus as claimed in any of Claims 1 to 8, wherein the nozzle arrangement comprises a number of nozzles, and the flow from one nozzle is directed at the workface and the flow from the other nozzles is directed at the cutting structures on the bit to act as mud picks.

11. Apparatus as claimed in Claim 10, wherein the internal geometry of the nozzles is such that there is greater flow in the one section of the bit compared to the remainder of the bit.

12. Apparatus as claimed in any of the preceding Claims, and substantially as described hereinbefore.

13. A method for causing deviation of a borehole being drilled by rotary drilling using a bit having at least one nozzle through which a drilling fluid is caused to flow such that in use the flow of drilling fluid through that nozzle allows one sector of the bit to cut more effectively than the remainder of the bit, the method comprising modulating the flow of the drilling fluid through that nozzle as the bit rotates such that the cutting action of the chosen sector is optimised when in the desired direction of deviation and is reduced at other locations in the borehole.

14. A method as claimed in Claim 13, wherein the modulation of the flow of drilling fluid is synchronised with the rotation of the bit in the borehole during drilling.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9325876.2

## Relevant Technical Fields

(i) UK Cl (Ed.M) E1F (FCU)

(ii) Int Cl (Ed.5) E21B

Search Examiner
D J HARRISON

Date of completion of Search
28 MARCH 1994

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) WPI

Documents considered relevant following a search in respect of Claims :-
1-14

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&: Member of the same patent family; corresponding document.

| Category | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| A | GB 2246151 A (CAMCO DRILLING GROUP LIMITED) | 1, 3 |
| A | US 4637479 A (LEISING) | 1, 3 |

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